Publications of the Korean Astronomical Society
30: 503 ∼ 505, 2015 September

pISSN: 1225-1534
eISSN: 2287-6936
http://dx.doi.org/10.5303/PKAS.2015.30.2.503

STAR FORMING ACTIVITY OF CLUSTER GALAXIES AT z∼1

Jae-Woo Kim, Myungshin Im, Seong-Kook Lee, and Minhee Hyun
Center for the Exploration of the Origin of the Universe, Department of Physics and Astronomy, Seoul National University, Seoul 151-742, Korea
E-mail: kjw0704@gmail.com

(Received November 30, 2014; Reviced May 31, 2015; Aaccepted June 30, 2015)

ABSTRACT

The galaxy cluster is an important object for investigating the large scale structure and evolution of galaxies. Recent wide and deep near-IR surveys provide an opportunity to search for galaxy clusters in the high redshift universe. We have identified candidate clusters of 0.8< z <1.2 from the 25 deg^2 SA22 field using an optical–near-IR dataset from merged UKIDSS DXS, IMS and CFHTLS catalogs. Using these candidates, we investigate the star forming activity of member galaxies. Consequently, at z ∼1, the star forming activity of cluster galaxies is not distinguishable from those of field galaxies, which is different from members in local clusters. This means the environmental effect becomes more important for $M_* > 10^{10} M_\odot$ galaxies at z <1.

Key words: galaxies: clusters : general – galaxies: evolution – galaxies: high-redshift

1. INTRODUCTION

It is well known that red galaxies are concentrated on the cluster core in the local universe. In contrast, many recent results have shown star formation in dense environments is active at z >1 (Cooper et al., 2008; Scoville et al., 2013). Therefore, galaxy clusters at z ∼1 are the best laboratory to understand the evolution of galaxies in the transition period of the universe. However, finding galaxy clusters has remained one of the major challenges in astronomy, especially at high redshift where cluster detection is difficult due to the lack of deep near-IR data and the rareness of massive systems. Here, we use a wide and deep near-IR dataset with deep optical survey data to find z ∼1 galaxy clusters and to investigate the star forming activity of cluster galaxies.

2. DATA AND METHODOLOGY

A wide and deep dataset is important for finding galaxy clusters in the distant universe. In particular, near-IR data plays a key role, as the bulk of stellar emission is redshifted into this regime.

We have used wide and deep datasets from the UKIRT Infrared Deep Sky Survey (UKIDSS, Lawrence et al., 2007) and the Infrared Medium-deep Survey (IMS, Im et al. in prep.) obtained by UKIRT. The Deep eXtragalactic Survey (DXS), the sub-survey of UKIDSS, surveyed 35 deg^2 areas composing 4 different regions with J_{AB} =23.2 and K_{AB} =22.7. The IMS mapped ∼120 deg^2 using Y- and J-bands for 7 different patches. Here, we chose the SA22 field where the area is covered by both surveys (25 deg^2) and a wide optical dataset exists.

The CFHT Legacy Survey (CFHTLS) imaged 155 deg^2 in 4 different regions using $ugriz$ filters. The whole area of the CFHTLS W4 field overlaps the SA22 field covered by both near-IR surveys. For this work, we used CFHTLS images from the Canadian Astronomy Data Centre (Gwyn, 2012).

This multi-wavelength dataset allows us to measure the photometric redshift of galaxies. In addition, this information is helpful for finding galaxy clusters efficiently, since it makes it possible to reduce the contamination by foreground and background galaxies. We estimated the photometric redshift of galaxies using the *Le Phare* software (Arnouts et al., 1999; Ilbert et al., 2006).

In order to find galaxy clusters, we split galaxies into redshift bins from z =0.8 to 1.2 with an increment of 0.02. Then the Voronoi Tessellation technique (Ebeling & Wiedenmann, 1993) was applied to measure the local density in each redshift bin. Finally, all dense regions from different bins were merged into one final candidate catalog. Additionally, the richness or mass (M) of candidate clusters were estimated by the algorithm of Andreon & Hurn (2010). In total, we identified ∼1200 candidates from the 25 deg^2 area. However, we used more prominent candidates with $M > 10^{13.7}$ for the analysis.

3. STAR FORMING ACTIVITY OF MEMBERS

The main purpose of this work is to readdress the star formation rate–density relation using galaxies in galaxy clusters. Since a galaxy cluster represents the densest

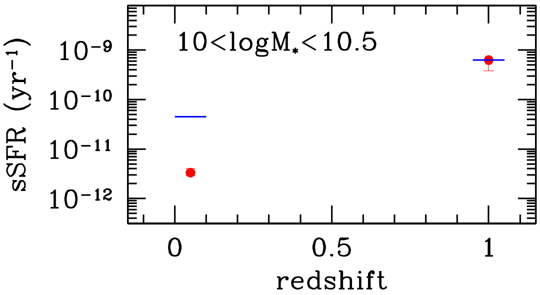

Figure 1. The median specific star formation rates for potential members (red points) and field galaxies (horizontal bars). The errors were estimated by the Bootstrap resampling method. The results for low redshift clusters from SDSS are also displayed. There is no significant difference of specific star formation rates between cluster and field galaxies at $z \sim 1$, which is different from local samples.

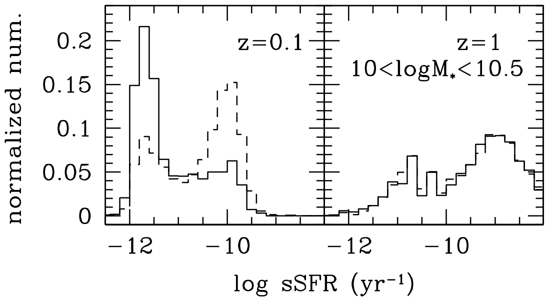

Figure 2. The sSFR distribution of $10^{10} < M_*/M_\odot < 10^{10.5}$ galaxies at $z \sim 0.1$ (left) and $z \sim 1$ (right). Solid and dashed histograms represent member and field galaxies, respectively. At $z \sim 1$, there is no significant difference of population compositions between field and cluster environments.

environment, studying the properties of member galaxies is one of the best ways to check environmental effects on the evolution of galaxies.

In order to estimate galaxy properties such as stellar mass (M_*) and star formation rate (SFR), we fit a template spectral energy distribution to the broad band photometry. The templates from Bruzual & Charlot (2003) were used with the assumptions of the Chabrier (2003) initial mass function, the Calzetti et al. (2000) dust attenuation curve and delayed star formation history (more details in Lee et al., 2010). In addition, potential members were defined by galaxies within a 500kpc radius and within the photometric redshift uncertainty.

Figure 1 shows the median specific SFR (sSFR) of potential members (red points) and field galaxies (horizontal bars). The results for low redshift clusters were based on the SDSS data. The low redshift clusters were from the SDSS cluster catalog (Millet et al. 2005), and the galaxy properties are from the MPA/JHU value added catalog (Kauffmann et al. 2003; Brinchmann et al. 2004). At low redshift, we can confirm that cluster galaxies show lower sSFR values than field galaxies. On the other hand, at $z \sim 1$, cluster members and field galaxies show a similar strength of star forming activities, which is different from the local samples.

This difference is caused by the composition of member galaxies. Figure 2 displays the normalized sSFR distribution of member (solid) and field (dashed) galaxies with $10^{10} < M_*/M_\odot < 10^{10.5}$ at low (left) and high (right) redshifts. It is clear that the composition of galaxy populations in cluster and field is similar at $z \sim 1$, leading to no significant difference in sSFRs.

4. SUMMARY

In this proceeding, we report preliminary result regarding the star forming activity of cluster galaxies at $z \sim 1$. We have used deep and wide optical-near-IR datasets to find galaxy clusters at high redshift, and to investigate the properties of cluster galaxies. We found no significant difference in star forming activity between cluster and field environments at z∼1, which is different from local samples. These results may indicate that environmetal effect in the dense region becomes more important at z<1 for galaxies with $M_* > 10^{10} M_\odot$. More details and the final result will be reported in the near future (Kim et al. in preparation).

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant, No. 2008-0060544, funded by the Korea government (MSIP). We are grateful to UKIDSS team, the staff in UKIRT, Cambridge Astronomical Survey Unit and Wide Field Astronomy Unit in Edinburgh. The United Kingdom Infrared Telescope is run by the Joint Astronomy Centre on behalf of the Science and Technology Facilities Council of the U.K. Based on observations obtained with MegaPrime/MegaCam, a joint project of CFHT and CEA/DAPNIA, at the Canada-France-Hawaii Telescope (CFHT) which is operated by the National Research Council (NRC) of Canada, the Institut National des Science de l'Univers of the Centre National de la Recherche Scientifique (CNRS) of France, and the University of Hawaii. This work is based in part on data products produced at the Canadian Astronomy Data Centre as part of the Canada-France-Hawaii Telescope Legacy Survey, a collaborative project of NRC and CNRS.

REFERENCES

Andreon, S. & Hurn, M. A., 2010, The Scaling Relation Between Richness and Mass of Galaxy Clusters: a Bayesian Approach , MNRAS, 404, 1922

Arnouts, S., Cristiani, S., & Moscardini, L., et al., 1999, Measuring and Modelling the Redshift Evolution of Clustering: the Hubble Deep Field North, MNRAS, 310, 540

Brinchmann, J., Charlot, S., White, S. D. M., Tremonti, C., Kauffmann, G., Heckman, T., & Brinkmann, J., 2004, The Physical Properties of Star-forming Galaxies in the Low-redshift Universe, MNRAS, 351, 1151

Bruzual, G. & Charlot, S., 2003, Stellar Population Synthesis at the Resolution of 2003, MNRAS, 344, 1000

Calzetti, D., Armus, L., & Bohlin, R. C., et al., 2000, The Dust Content and Opacity of Actively Star-forming Galaxies, ApJ, 533, 682

Chabrier, G., 2003, Galactic Stellar and Substellar Initial Mass Function, PASP, 115, 763

Cooper, M. C., Newman, J. A., & Weiner, B. J., et al., 2008, The DEEP2 Galaxy Redshift Survey: the Role of Galaxy Environment in the Cosmic Star Formation History, MNRAS, 383, 1058

Ebeling, H. & Wiedenmann, G., 1993, Detecting Structure in Two Dimensions Combining Voronoi Tessellation and Percolation, PhRvE, 47, 704

Gwyn, S. D. J., 2012, The Canada-France-Hawaii Telescope Legacy Survey: Stacked Images and Catalogs, AJ, 143, 38

Ilbert, O., Arnouts, S., & McCracken, H. J., et al., 2006, Accurate Photometric Redshifts for the CFHT Legacy Survey Calibrated Using the VIMOS VLT Deep Survey, A&A, 457, 841

Kauffmann, G., Heckman, T. M., & White, S. D. M., et al., 2003, Stellar Masses and Star Formation Histories for 105 Galaxies from the Sloan Digital Sky Survey, MNRAS, 341, 33

Lawrence, A., Warren, S. J., & Almaini, O., et al., 2007, The UKIRT Infrared Deep Sky Survey (UKIDSS), MNRAS, 379, 1599

Lee, S. -K., Ferguson, H. C., Somerville, R. S., Wiklind, T., & Giavalisco, M., 2010, The Estimation of Star Formation Rates and Stellar Population Ages of High-redshift Galaxies from Broadband Photometry, ApJ, 725, 1644

Miller, C. J., Nichol, R. C., & Reichart, D., et al., 2005, The C4 Clustering Algorithm: Clusters of Galaxies in the Sloan Digital Sky Survey, AJ, 130, 968

Scoville, N., Arnouts, S., & Aussel, H., et al., 2013, Evolution of Galaxies and Their Environments at z = 0.1-3 in COSMOS, ApJS, 206, 3